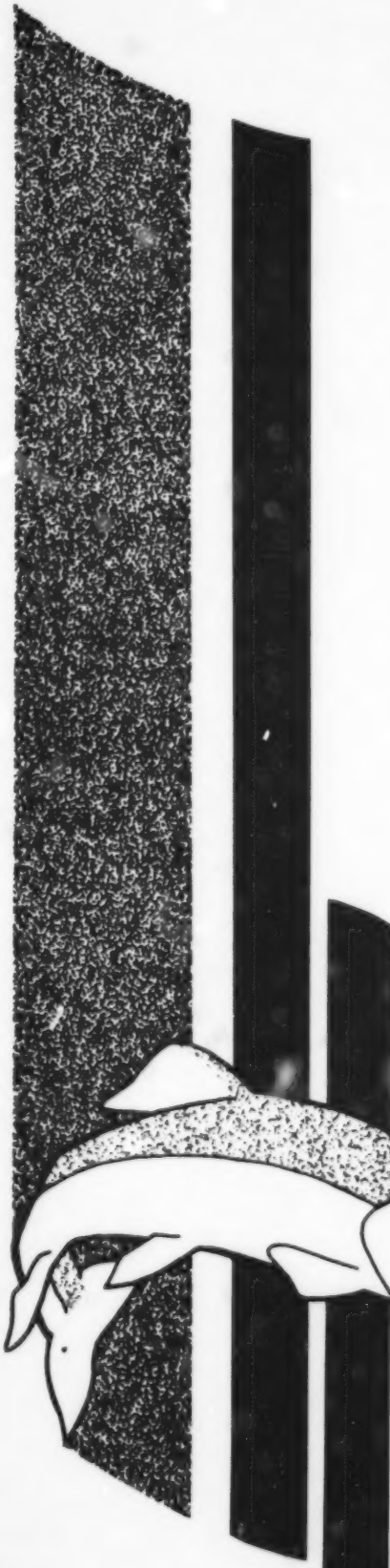




A Comparison of Precociousness in Three Graded Size Classes of Hatchery-Reared Rainbow Trout (*Salmo gairdneri*)

by

Kanji Tsumura

Jeremy M. B. Hume

FISHERIES TECHNICAL CIRCULAR No. 75
1986



Province of British Columbia
Ministry of Environment and Parks

A COMPARISON OF PRECOCIOUSNESS IN
THREE GRADED SIZE CLASSES OF HATCHERY-REARED
RAINBOW TROUT (Salmo gairdneri)

by

Kanji Tsumura¹

Jeremy M.B. Hume¹

¹Ministry of Environment and Parks, Recreational Fisheries
Branch, 2204 Main Mall, University of British Columbia,
Vancouver, B.C., V6T 1W5

Fisheries Technical Circular No. 75
1986

Canadian Cataloguing in Publication Data

Tsumura, K. (Kanji), 1940-

A comparison of precociousness in three graded
size classes of hatchery-reared rainbow trout
(*Salmo gairdneri*)

(Fisheries technical circular, ISSN 0229-1150 ;
no. 75)

Bibliography: p.
ISBN 0-7726-7079-X

1. Rainbow trout - Growth. I. Hume, Jeremy M. B.,
1948- . II. British Columbia. Ministry of
Environment and Parks. III. Title. IV. Series.

SH167.R34T78 1986 639.3'755 C87-092059-6

ABSTRACT

Tsumura, K. and J.M.B. Hume. A Comparison of Precociousness in Three Graded Size Classes of Hatchery-Reared Rainbow Trout (*Salmo gairdneri*). 1986. Fisheries Technical Circular No. 75, 10 p.

Growth and maturation rates of hatchery reared juvenile rainbow trout (*Salmo gairdneri*, Pennask Lake stock) were compared in two groups of fish sorted into three size classes (small, < 70 mm; medium, 80-94 mm; large $\geq$ 115 mm). One group consisted of progeny from four-year-old virgin spawners (selected) and the other, from the annual egg collection conducted by Summerland Trout Hatchery (unselected) from mainly 3 yr old spawners. Trout were reared in a hatchery from May 5 to October 29, 1984 at 15°C with a food ration of 2% of body weight per day under simulated natural photoperiods.

For selected and unselected groups combined, the proportion of mature males averaged 1.7%, 10.9% and 49.2% for the small, medium and large size classes, respectively. Grading is suggested as a technique to decrease the number of precocious males being stocked into quality lakes. There were no significant differences in male maturation rates between the selected and unselected groups for the three size classes.

ACKNOWLEDGEMENTS

The authors thank R.A.H. Sparrow, Larry Lemke and the Summerland Trout Hatchery fish culturists, Dan O'Sullivan, Graham Tyler, Renee Ritchey, Klaus Wolff, Rory Smith and Eleanor Knorr for their support in collecting the eggs and rearing the juvenile fish. Marge Sidney from the Kamloops regional office assisted in the scale readings. Bob Land, Larry Mitchell and Morley Rempel raised the fish as yearlings under experimental conditions at the Research and Development Section Hatchery.

Eric Parkinson provided continued support. Ken Ashley, Angelo Facchin, Bing Warner and Doris McKay contributed to the preparation and completion of the manuscript. P. A. Slaney reviewed the paper and offered many helpful suggestions.

Special thanks to N.T. Johnston in assisting with the collection of the data, and to Carin Magnhagen and Dr. T.G. Northcote, Institute of Animal Resource Ecology, University of British Columbia, for translating the Norwegian references.



INTRODUCTION

Rainbow trout (*Salmo gairdneri*), as in most other salmonid species, produce males which mature early and spawn as two year olds (Hard et al. 1985; Tofteberg 1982; Gardner 1976). Rapid growth rates in the first year regulated by environmental factors including rearing temperature, photoperiod, availability of food (Houston 1981; Schmidt and House 1979; Hager and Noble 1976) as well as genetic factors (Thorpe et al. 1983; Kincaid et al. 1977; Donaldson and Olson 1955) are known to affect sexual maturation rates. In their first year, fork lengths and body weights of two-year-old rainbow trout spawners are usually greater than the later maturing ones (Tofteberg 1982; Hallingstad 1978; Kincaid et al. 1977). With the onset of sexual maturity, growth rate is reduced, flesh quality deteriorates, physical appearance becomes unattractive and mortality increases in trout (Tofteberg and Hansen 1986; Naevdal 1983; Campbell 1971), as well as in other salmonid species (Gjerde 1984; Dalley et al. 1983; Gardner 1976). These fish contribute little to a sports fishery. Although mature males improve in quality throughout the summer they never attain the same quality as fish that did not mature.

This study was conducted to determine the feasibility of grading out faster growing juvenile rainbow trout in a hatchery population to reduce the number of precocious males in the lake stocking programme in British Columbia. Studies of coho salmon (*Onchorhynchus kisutch*) have shown that hatchery stocks can be graded to select for early or late maturation (Bilton et al. 1982; Hager and Noble 1976).

In Pennask Creek the spawning run of 3-yr and older fish in 1985 consisted of 29.8% virgin 4-yr-old spawners and 70.2% that first spawned as 2- or 3-yr olds (Tsumura and Hume 1987a). The effect of selecting four-year-old maiden spawners as a brood stock to reduce precocity in hatchery reared rainbow trout was therefore investigated concurrently.

METHODS

Rainbow trout for this experiment were progeny from the 1983 spring egg collection conducted by the Summerland Trout Hatchery at Pennask Creek, the inlet to Pennask Lake, in southwestern British Columbia. Two groups of eggs were collected. The first was from the annual collection of about 1.4 million eggs, where spawners were stripped at random (unselected). Both age of maturity and repeat spawning traits were disregarded in both male and female brood fish. The second group (73,500 eggs) was collected from four-year-old maiden spawners fertilized with sperm from four-year-old virgin males

(selected). Ages and repeat spawning were determined from scale readings. Both groups of eggs were incubated at the Summerland Trout Hatchery, and the fish were reared under their conventional hatchery regime in troughs at 10°C until May 1984.

Three size classes of fish were sorted from each of the selected and unselected groups (Table 1) on May 5, 1984, from length frequencies determined on April 11. The small, medium, and large size classes consisted of fish with fork lengths < 70 mm, 80 to 94 mm, > 115 mm, respectively. These fish groups were anaesthetized using 2-phenoxyethanol, measured, weighed to the nearest 0.1 g, and clipped for later identification.

The three classes of fish were transported to the Research and Development Hatchery at Abbotsford and were reared in a 1.8 m diameter circular tank (capacity approx 2,400 L) at 15°C. They were fed a ration of 2% of body weight per day and the photoperiod was regulated to simulate natural conditions. Fish were sacrificed on October 29, 1984 and examined for precocious development. Lengths, weights, and gonad weights were measured. Sexual maturity was determined by visual inspection of the gonads and was later confirmed by calculation of a gonadosomatic index (Houston, 1981).

Table 1. Initial lengths and weights on May 5, 1984 at the start of the experiment at Summerland Trout Hatchery.

Group	Size Class	N	Mean Length (mm)	Mean Weight (g)
Selected	Small (< 70 mm)	28	67.1	3.3
	Medium (80-94 mm)	100	88.3	7.1
	Large (> 115 mm)	100	126.8	22.9
Unselected	Small (< 70 mm)	28	71.2	3.7
	Medium (80-94 mm)	100	88.1	7.1
	Large (> 115 mm)	100	125.3	21.1
All Fish	Small (< 70 mm)	56	69.2	3.5
	Medium (80-94 mm)	200	88.2	7.1
	Large (> 115 mm)	200	126.1	22.0

RESULTS

INITIAL SIZE

Length frequency of selected and unselected juveniles were similar when measured on April 11, 1984 (Fig. 1). In the selected group the population consisted of 4.1, 40.2, and 9.1% for the small, medium and large size classes respectively and for the unselected group it consisted of 5.8, 33.1, and 12.4% for the same respective size classes. Mean length of selected fish was 92.1 mm and 91.6 mm for the unselected fish.

Mean lengths and weights at the start of the experiment were not significantly different between selected and unselected groups within each size class (ANOVA, $P < 0.05$).

MATURATION RATES AND SEX RATIO

The large size class in both selected and unselected groups (Table 2) had significantly higher precociousness rates than the other two size classes (G test, $P < 0.05$). Average rates of precocious development were 1.7, 10.9 and 49.7% for the small, medium and large classes, respectively. There was no significant difference between small and medium precociousness rates in the selected fish. However, within the unselected fish, the medium group matured at a higher rate than the small group ($P < 0.05$). There were no differences between selected and unselected groups within each size class ($P < 0.05$). Maturing females were not found in any of the samples.

Table 2. Comparison of sex and male maturity in the three size classes of selected and unselected Pennask Lake rainbow trout yearlings.

Group		Total #	Males				Females	
			All Males N	Males %	Mature Males N	Males %	N	%
Selected	Small	31	17	54.8	1	3.2	14	45.2
	Medium	85	35	41.2	5	5.9	50	58.8
	Large	95	59	62.0	49	51.6	36	38.0
Unselected	Small	27	11	40.7	0	0	16	59.3
	Medium	90	45	50.0	14	15.6	45	50.0
	Large	96	54	56.0	46	47.9	42	44.0
All fish	Small	58	28	48.3	1	1.7	30	51.7
	Medium	175	80	45.7	19	10.9	95	54.3
	Large	191	113	59.2	95	49.7	78	40.8

Group	N
Unselected	136
Selected	219

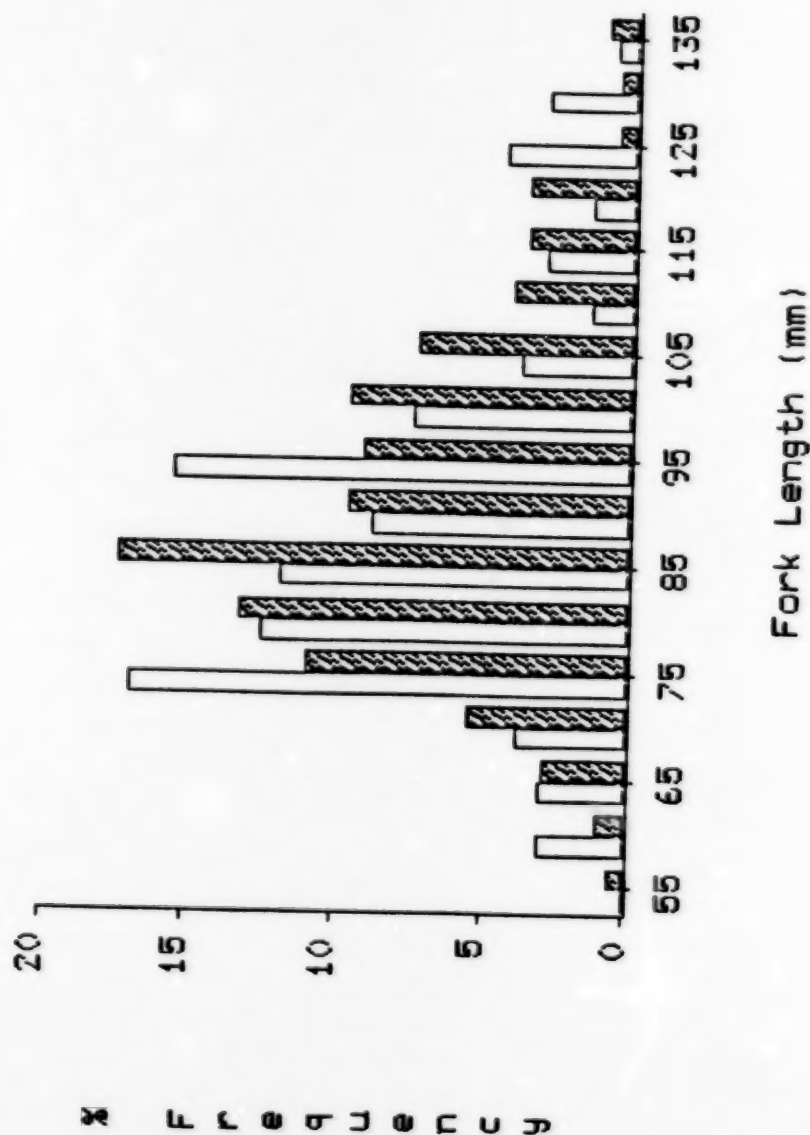


Fig. 1. Length frequency of selected and unselected juveniles at Summerland Trout Hatchery on April 11, 1984.

Only the large size class in the selected group had a sex ratio that was significantly different from 1:1, or from any of the other groups ($P < 0.05$). There was, however, a tendency for the larger classes to have more males than the smaller ones (Table 2).

GROWTH

Growth rates could be compared between selected and unselected fish by comparing final lengths and weights because they were initially the same (Table 1). Overall, there were no significant differences in mean weights between the selected or unselected groups (Table 3, $P < 0.05$). Within the sexes, only the large mature male fish from the selected group was significantly different from the unselected fish ($P < 0.05$). In all cases where sample sizes were adequate (>5), the mature males were significantly larger than either the females or immature males ($P < 0.05$). The precocious males were on the average 34.1, 18.8 and 15.3% longer than the other fish within the small, medium and large size classes respectively. By weight, the precocious males were 2.6, 6.9 and 13.6% heavier within the same size classes.

Within both groups mean length and weight of the large size class was significantly larger than the medium size class which in turn was significantly larger than the small size class. There was approximately a 25% decrease in length and over 50% decrease in weight between each size classes (Table 3). These differences are caused mainly by the differences in initial length and weight because the calculated growth rates were very similar between size classes (Table 3).

DISCUSSION

GRADING

Growth rates within the first year are an underlying factor associated with early sexual maturation in male rainbow trout. In studies by Tofteberg and Hansen (1986), mature males at age 2 were generally larger than those immature as 2-yr-old males. Houston (1981) indicates that the critical weight for early maturity in Premier Lake rainbow trout was between 10 and 20 g at the end of their first year. He suggests that different stocks would have different critical weights and some small males would mature while some of the larger ones remained immature. In our study only 18.5% of the males in the smaller size classes matured compared to 84.1% for the large size class. There was a significant difference in the maturation rates between the juvenile fish which initially averaged 22.0 g and the smaller fish which averaged 7.1 grams or less. This is consistent with results obtained for coho salmon by Hager and Noble (1976). The smaller size classes with lower rates of precocious development

Table 3. Comparison of final length, weight, and instantaneous growth rates on October 29, 1984.

A. Fork Length											
Group	Size Class	Males						Females		All Fish	
		Immature		Mature		All Males		Immature			
		N	mm	N	mm	N	mm	N	mm	N	mm
Selected	Small	16	134	1	220	17	139	14	140	31	140
	Medium	30	187	5	217	35	191	50	176	85	182
	Large	10	241	49	284	59	277	36	232	95	260
Unselected	Small	11	158	0	-	11	158	16	151	27	154
	Medium	31	189	14	231	45	202	45	193	90	198
	Large	8	253	46	275	54	271	42	238	96	257
All Fish	Small	27	144	1	220	28	147	30	146	58	146
	Medium	61	188	19	227	80	197	95	182	175	190
	Large	18	246	95	280	113	274	78	235	191	258

B. Weight							
Group	Size Class	Immature g	Males		All Males g	Females Immature g	All fish g
			Mature g				
Selected	Small	30.9	126.2		36.5	35.8	36.2
	Medium	79.7	135.7		87.7	61.1	72.1
	Large	180.2	296.8		277.0	150.6	229.1
Unselected	Small	47.7	-		47.7	35.8	40.6
	Medium	80.0	160.4		105.0	81.3	93.2
	Large	199.4	249.9		242.4	162.6	207.5
All fish	Small	37.7	126.2		40.9	35.8	38.2
	Medium	79.7	153.9		97.4	70.7	83.0
	Large	188.7	274.1		260.5	157.1	218.2

C. Instantaneous Growth Rates (weight)							
Group	Size Class	Immature G	Males		All Males G	Females Immature G	All fish G
			Mature G				
Selected	Small	.012	.020		.013	.013	.013
	Medium	.014	.017		.014	.012	.013
	Large	.012	.015		.014	.011	.013
Unselected	Small	.015	-		.015	.013	.014
	Medium	.014	.018		.015	.014	.015
	Large	.012	.014		.014	.011	.013
All fish	Small	.013	.020		.014	.013	.014
	Medium	.014	.017		.015	.013	.014
	Large	.012	.014		.014	.011	.013

will mature later as 3- or 4-yr-old trout, as suggested by Tofteberg (1982).

The number of precocious males produced under hatchery or natural conditions can be substantial. Our estimates of early maturing (age 2) rainbow trout in progeny of a wild broodstock (Pennask Lake) reared in a hatchery and liberated into lakes of varying productivity range from 18.5 to 40.1% for lakes sampled by gillnetting (Tsumura and Hume 1987a). This is equivalent to the production of 185,000 to 401,000 precocious males per million fish stocked into lakes in the provincial hatchery programme. Their contribution to the sport fishery is probably marginal owing to limited growth, survival, and quality. In our studies with precocious and non-precocious Pennask Lake rainbow trout stocked in equal numbers in an experimental lake, there was a significant difference in the relative survival rates observed in the two groups (Tsumura and Hume 1987b). Samples collected in the fall, after the spawning period suggested a relative survival rate of 53% for the precocious males when compared to the nonprecocious fish. Therefore, grading could be an effective strategy in the stocking programme to decrease the incidence of precociousness and early mortality of trout in selected lakes.

Pennask Lake juveniles are currently liberated annually into 60 to 80 interior lakes. Stocking rates range from 1,000 to 30,000 fish or more, but the majority of the lakes receive less than 10,000. Many of these lakes have angling restrictions limiting the daily catch quota to two fish. These quality lakes would benefit appreciably from a grading programme carried out prior to liberation. A greater proportion of fish biomass production would be directed into somatic growth rather than gonadal development, and there would be an increase in the number of later maturing fish available in the fishery. Stocking rates may have to be reduced to compensate for increased longevity if the growth rate is to be maintained in these quality lakes.

Many of our small productive lakes and ponds in the interior of the province are not stocked because of a high winterkill potential. These lakes and ponds can be brought into production by stocking them with the upper size class of fish graded from the juvenile population prior to the spring liberations. These fish may attain a catchable size by late summer and provide a fall and winter fishery where none was existent before. These fish should be able to survive in most of our winterkill lakes until February (Ken Ashley, pers. comm.) before the dissolved oxygen is decreased to levels that rainbow trout do not survive. An experiment testing the feasibility of this strategy is reported in Tsumura, Hume and Chan (1987). The results indicate that at least 56% of the fish will weigh over 340 g in the fall and 70% of these fish will be precocious males.

SELECTION

Altering the age of sexual maturation and other genetically heritable traits have been investigated in salmonid selection studies with some success. Gjerde (1984) demonstrated that in Atlantic salmon, age of sexual maturity of the parents is highly correlated with the age of sexual maturity of the offspring, and that selection for age at sexual maturity is highly heritable. In selection studies on growth, increases were observed through three generations under laboratory conditions and through the fourth generation under hatchery conditions for progeny from two-year old maturing rainbow trout (Kincaid et al 1977). Genetic and improving environmental factors contributed to the increase in overall growth rates, but the selection process was shown to enhance growth rates when compared to the control group. This suggests that selective breeding in rainbow trout can reduce genetic variability in a population so that desired genetic traits will predominate in the progeny of selected broodstock in increasing numbers with each successive generation. Therefore, it should be possible to reduce the percentage of early maturing rainbow trout by selectively breeding late maturing fish.

In our study, the difference in early sexual maturation rates between the selected and unselected groups was not significant, maybe because several years of selection are required. It is suggested by Tofteberg and Hansen (1986) that late maturing fish may not be genetically coded for maturation at one particular age and that environmental effects at an early age can dominate the age of maturation. In our case, progeny of the slow growing Pennask Lake rainbow trout were raised at optimal growing conditions in the hatchery, compared to an environment of low productivity, Pennask Lake, for the broodstock. This contrast in the rearing environment confounded with the genetic make up of the spawning run at Pennask Creek (ie 30% virgin 4-yr-old spawners) may have obscured any positive gain from the selection process in this experiment. Although the first generation of selected fish are not indicative of an improved line of fish, a continuing selection programme may eventually show a trend to later sexual maturation as suggested by Naevdal (1983).

REFERENCES

- Bilton, H.T., D.F. Alderdice, and J.T. Schnute. 1982. Influence of time and size at release of juvenile coho salmon (Oncorhynchus kisutch) on returns at maturity. Can. J. Fish. Aquat. Sci. 39:426-447.
- Campbell, R.N. 1971. The growth of brown trout, Salmo trutta L. in northern Scottish lochs with special reference to the improvement of fisheries. J. Fish. Biol. 3:1-28.
- Dalley, E.L., C.W. Andrews, and J.M. Green. 1983. Precocious male Atlantic salmon parr (Salmo salar) in insular Newfoundland. Can. J. Fish. Aquat. Sci. 40:647-652.
- Donaldson, L.R. and P.R. Olson. 1955. Development of rainbow trout brood stock by selective breeding. Trans. Am. Fish. Soc., 85:93-101.
- Gardner, M.L.G. 1976. A review of factors which may influence the sea-age and maturation of Atlantic salmon, Salmo salar L. J. Fish. Biol. 9:289-327.
- Gjerde, B. 1984. Response to individual selection for age at sexual maturity in Atlantic salmon. Aquaculture, 38:229-240.
- Hager, R.C. and R.E. Noble. 1976. Relation of size at release of hatchery-reared coho salmon to age, size, and sex composition of returning adults. Prog. Fish Cult., 38:144-147.
- Hallingstad, F. 1978. Sortering og kjønnsmodning hos regnebueørret. (Grading and early maturation of rainbow trout). Nor. Fiskeoppdrett, 3(1):9-10 (in Norwegian).
- Hard, J.J., A.C. Wertheimer, W.R. Heard and R.M. Martin. 1985. Early male maturity in two stocks of chinook salmon (Oncorhynchus tshawytscha) transplanted to an experimental hatchery in southeastern Alaska. Aquaculture, 48:351-359.
- Houston, C.J.G. 1981. Factors affecting precocious sexual development in male rainbow trout. M.Sc. Thesis. Dept. of Zoology, University of British Columbia. 31 pp.
- Kincaid, H.L., W.R. Bridges and B. von Limbach. 1977. Three generations of selection for growth rate in fall-spawning rainbow trout. Trans. Am. Fish. Soc., 105:621-628.
- Naevdal, G. 1983. Genetic factors in connection with age at maturation. Aquaculture, 33:97-106.

- Schmidt, S.P. and E.W. House. 1979. Precocious sexual development in hatchery-reared and laboratory-maintained male steelhead trout (Salmo gairdneri). J. Fish. Res. Board Can. 36:90-93.
- Thorpe, J.E., R.I.G. Morgan, C. Talbot and M.S. Miles. 1983. Inheritance of developmental rates in Atlantic salmon, Salmo salar L. Aquaculture, 33:119-128.
- Tofteberg, P. 1982. Sammenheng mellom vekst og alder ved kjønnsmodning i oppdrett av regnbueørret, Salmo gairdneri. MSc. Thesis, Inst. Fish. Biol., Univ. Bergen, 106 p. (in Norwegian).
- Tofteberg, P. and T. Hansen. 1986. Relationship between age at maturity and growth rate in farmed rainbow trout, Salmo gairdneri. EIFAC/FAO Symposium on Selection, Hybridization and Genetic Engineering in Aquaculture of Fish and Shellfish for Consumption and Stocking. Bordeaux (France), 27-30 May 1986. 35 pp.
- Tsumura, K., and J.M.B. Hume. 1987a. The effects of selection and growth rates on the early sexual maturation rates of rainbow trout (Salmo gairdneri). Fish. Proj. Rept. RD 3 (in prep).
- Tsumura, K., and J.M.B. Hume. 1987b. Post-spawning growth and relative survival of precocious rainbow trout (Salmo gairdneri). Fish. Proj. Rept. RD 4, 9 p.
- Tsumura, K., J.M.B. Hume and B. Chan. 1987. The effects of size at release in rainbow trout (Salmo gairdneri) stocked in a winterkill lake. Fish. Mgmt. Rept. (in prep).

List of previous Fisheries Technical Circulars

- 1985 69 Bruce, P.G. and P.J. Starr. Fisheries Resources and Fisheries Potential of Williston Reservoir and its Tributary Streams.
- 69A Bruce, P.G. and P.J. Starr. Photo-Documentation of Williston Lake Tributaries for the 1975 Assessment of Fisheries Resource Potential.
- 1986 70 Dixon, B.M. Age, Growth and Migration of White Sturgeon in the Nechako and Upper Fraser Rivers of B.C.
- 1986 71 Billings, S.J. Steelhead Harvest Analysis, 1984-85.
- 1986 72 Carswell, L.B., R.S. Hooton and V.A. Lewynsky. Campbell/Quinsam River Creel Surveys, 1975-76 to 1979-80.
- 1986 73 Clark, B.J. and A.R. Facchin. The 1984 Chilliwack-Vedder River Steelhead Creel Survey.
- 1986 74 Lirette, M.G., R.S. Hooton and V.A. Lewynsky. Preliminary Steelhead Production Capability Estimates for Selected Vancouver Island Streams.

List of previous Management Reports

- 1984 83 Parkinson, E., R.J. Behnke and W. Pollard. A morphological and electrophoretic comparison of rainbow trout (Salmo gairdneri) Above and Below Barriers on Five Streams on Vancouver Island, B.C.
- 1985 84 A Questionnaire Survey of Vancouver Island Steelhead Anglers' Opinions and Preferences on Management Issues.
- 1985 85 Big Qualicum River Steelhead Fishery Investigations, 1976 to 1981.
- 1986 86 Hooton, R.S. & M.G. Lirette. Telemetric Studies of Winter Steelhead, Gold River, 1982-83.
- 1986 87 Parkinson, E.A. Skaha Hatchery Evaluation.
- 1986 88 Hooton, R.S. B.R. Ward, V.A. Lewynsky, M.G. Lirette and A.R. Facchin. Age and Growth of Steelhead in Vancouver Island Populations.
- 1986 89 Slaney, P.A. An Assessment of the Rainbow Trout (Salmo gairdneri) Population in the Upper Nechako River and the Effects of a Sportfishery Closure.